Measurement of Turbulent Fluxes and Dissipation Rates in the Coastal Bottom Boundary Layer

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LONG-TERM GOALS

The long-term goals of this project are to quantify turbulence and to understand the mechanisms and implications of turbulent mixing in the bottom boundary layer of the coastal ocean.

OBJECTIVES

This project, which is a component of the Coastal Mixing and Optics (CMO) program, includes measurements and analysis aimed at quantifying turbulence and elucidating turbulence dynamics within the bottom boundary layer on the New England continental shelf. The objectives of the measurements are (1) to determine the vertical structure of Reynolds-averaged velocity and temperature; (2) to obtain direct covariance estimates of turbulent momentum and heat fluxes; and (3) to obtain indirect inertial-range estimates of dissipation rates for turbulent kinetic energy and temperature variance. The objectives of the analysis are (1) to close approximate budgets for turbulent kinetic energy and temperature variance; (2) to quantify the intensity and scale of vertical mixing; and (3) to test existing turbulence-closure models, which predict the dependence of momentum and heat fluxes on vertical gradients of Reynolds-averaged velocity and temperature. This project differs from previous observational studies of boundary layer dynamics on shelves because it aims at measurements, rather than inferences, of the most important turbulence statistics, and because it resolves not only the classically studied logarithmic wall layer, but also the outer boundary layer, where scaling and model predictions indicate that stable stratification has a major influence on turbulence dynamics, and where rigorous tests of turbulence closure models have not previously been attempted.

APPROACH

The measurement approach is deployment of a bottom tripod fitted with sensors designed to measure the Reynolds-averaged and fluctuating components of velocity and temperature at several heights above bottom. The primary instrumentation is a set of seven BASS acoustic travel-time velocity sensors aligned in a vertical array between 0.3 and 7.0 m above bottom and co-located with an array of fast-

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response thermistors. BASS sensors have recently been modified to determine sound speed, in addition to fluid velocity, so that they provide indirect information about temperature and density. Secondary instrumentation includes a pair of temperature-conductivity sensors and a pressure sensor. A late addition was a set of three Sontek acoustic Doppler velocimeters (ADVs), all at 0.3 m above bottom and with a horizontal separation of approximately 2 m.

The instrumentation provides measurements that resolve the vertical structure of Reynolds-averaged velocity and temperature, in addition to providing direct covariance measurements of turbulent momentum and heat fluxes and indirect inertial-range estimates of dissipation rates for turbulent kinetic energy and for temperature variance. The measurements determine the dominant terms in the turbulent kinetic energy equation (production, dissipation and buoyancy flux) and the dominant terms in the equation for temperature variance (production and dissipation). The measurements will permit estimates of the scale of the energy-containing turbulent motions (via spectra of vertical velocity), estimates of eddy diffusivities, and tests of turbulence closure models (i.e., proposed relationships between turbulent fluxes and vertical gradients of Reynolds-averaged velocity and temperature).

WORK COMPLETED

We completed acquisition of the instrumentation, fabrication of the bottom tripod, and testing of the measurement system at Woods Hole during spring and summer of 1996. We deployed the tripod at the central CMO site on the New England shelf in August of 1996. During turnaround cruises in October, January, April and June, we recovered the tripod, cleaned and repaired the instrumentation as needed, off-loaded data, and re-deployed the tripod. Final recovery of the tripod occurred in August of 1997.

Analysis to date has focused separately on the ADV and BASS measurements. The ADV measurements have provided covariance estimates of near-bottom Reynolds stress and inertial-range estimates of dissipation. The analysis of ADV measurements has focused primarily on effects of spatial filtering (due to the finite sample volume) and viscosity (due to the finite Kolmogorov scale) on high-wavenumber spectra and on dissipation estimates. The analysis of BASS data has focused primarily on estimates of heat and momentum fluxes, estimates of dissipation rates, closure of budgets for turbulent kinetic energy and temperature variance, and tests of flux-profile relationships for heat and momentum.

RESULTS

Our work on ADV measurements establishes that near-bottom velocity spectra are consistent with theoretical predictions based on the Kolmogorov model if we include effects of viscous dissipation and spatial filtering. This finding is significant because previous results published in the oceanographic literature, based on lower-quality measurements from older sensors, indicate a much larger Reynolds number effect than can be accounted for by existing models of viscous effects.

Our work on BASS measurements has resulted in approximate closure of budgets for turbulent kinetic energy and temperature variance under conditions sufficiently energetic that the noise levels of the measurements are exceeded by the turbulence. This result indicates that our estimates of turbulent heat flux and turbulent momentum flux have quality sufficient for definitive tests of flux-profile relationships.

Our work on BASS measurements also indicates that our estimates of Reynolds stress and shear are not consistent with the law of the wall, which is the simplest flux-profile relationship. Stratification by temperature and salinity is too small to explain the observed departure from the law of the wall within the context of Monin-Obukhov similarity theory. The likely explanation is stratification due to suspended sediment and the small thickness of the bottom boundary layer.

The attached figure shows example results obtained from BASS measurements. The top panel shows low-pass-filtered (i.e., subtidal) alongshore component of turbulent Reynolds stress at four heights above bottom. The middle panel shows low-pass-filtered turbulent heat flux at four heights above bottom. The bottom panel shows low-pass-filtered turbulence production and low-pass-filtered turbulence dissipation, averaged over four heights. To our knowledge, these are the first time-series estimates of turbulent Reynolds stress and turbulent heat flux obtained by direct covariances on the open shelf. The fact that production estimates nearly balance dissipation estimates (bottom panel) indicates that the flux estimates are meaningful.

IMPACT/APPLICATIONS

Our findings regarding high-frequency spectra of vertical velocity will impact future studies in which these spectra are used to infer turbulence statistics such as dissipation rate and bottom stress. Our findings regarding the flux-profile relationship for momentum will impact use of the law of the wall as a means of estimating bottom stress, and they will lead to a test of commonly used turbulence closure models.

RELATED PROJECTS

We have interacted with Paul Hill, who has obtained novel results regarding particle size by means of camera observations at the central CMO site. Our velocity measurements and estimates of turbulence statistics have permitted Paul to put his measurements into a dynamical context.

PUBLICATIONS

Hill, P.S., Voulgaris, G. and Trowbridge, J.H. Floc breakup in the ocean. Submitted to Nature.

Shaw, W. J., Williams, A. J. and Trowbridge, J. H. 1996. Measurement of Reynolds stress and heat flux with an acoustic travel-time meter. Proceedings of Oceans '96, IEEE/MTS, New York.

Trowbridge, J. H., Williams, A. J. and Shaw, W. J. 1996. Measurements of Reynolds stress and heat flux with an acoustic travel-time current meter. Proceedings of an ONR workshop on microstructure sensors, Mt. Hood, Oregon.

Trowbridge, J. H. On a technique for measurement of turbulent Reynolds stress in the presence of surface waves. J. Atmos. Oceanic Technol., 15, 290-298.

Voulgaris, G., Trowbridge, J. H., Williams, A. J. and Shaw, W. J. 1997. High-resolution measurements of turbulent fluxes and dissipation rates in the benthic boundary layer. Proceedings of Coastal Dynamics '97, Plymouth, U. K.

Voulgaris, G. and Trowbridge, J. H. Evaluation of the acoustic Doppler velocimeter (ADV) for turbulence measurements. J. Atmos. Oceanic Technol., 15, 272-289.